4.7 ESTIMATING AGRICULTURAL WATER CONSERVATION POTENTIAL

The methodology used to estimate agricultural water conservation potential that may result from implementing the Water Use Efficiency Program is described in this subsection. The methodology consists of:

- Input data necessary to develop estimates,

- Assumptions made to interpret and analyze data, and

- Presentation of conservation estimates: No Action Alternative versus a CALFED Program solution and farm-level versus district-level savings.

These estimates were developed to help understand the potential role conservation could play in the larger context of statewide water management, as well as to provide information for the programmatic-level impact analysis. **These estimates are not targets or goals and should not be interpreted as such,** or used for planning purposes.

DEFINING THE DATA

Misuse of terminology can cause significant difficulties with understanding and interpreting the data. To help ensure consistency in using key terms, CALFED adopted the DWR definitions described below.

From DWR's January 1998, public review draft of "The California Water Plan Update: Bulletin 160-98":

Applied Water Demand: The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- The intake to a city water system or factory
- The farm headgate or other point of measurement
- A managed wetland, either directly or by drainage flows.

Irrecoverable Losses: The water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility, drainage canal, or fringe areas (for example, surface runoff from a farm field that flows to an evaporation pond).

Recovered Losses: The water returning to a local surface water or groundwater source available for other beneficial uses (for example, surface runoff from a farm field that flows back to a surface stream used by other downstream beneficiaries, including the environment).

Depletion (DEP): The water consumed in a service area and no longer available as a source of supply. For agriculture and wetlands, depletion is evapotranspiration of applied water plus irrecoverable losses. This amount can include conveyance evaporation and evapotranspiration of vegetation lining delivery systems.

Evapotranspiration (ET): The quantity of water transpired (given off), retained in plant tissue, and evaporated from plant tissue and surrounding soil surfaces.

Evapotranspiration of Applied Water (ETAW): The portion of total evapotranspiration that is provided by irrigation. This value is adjusted to account for portions of rainfall that help meet ET.

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4.7.1 INPUT DATA NECESSARY TO DEVELOP ESTIMATES

Input data are one of the most important pieces of information when performing a technical analysis because the quality of the data directly bears on the analytical results. Therefore, it is crucial that the data are reliable and widely accepted as credible and applicable for the analysis. With this in mind, the CALFED Program obtained the best available data on regional agricultural water use for its agricultural water conservation analysis.

DWR has collected agricultural water use data for nearly 40 years throughout the state; these records are among the most thorough of their kind. DWR's data regarding historical and "normalized" water use is widely accepted as an accurate picture of existing and historical agricultural water use conditions. To estimate conservation potential, CALFED used normalized 1995 data. These data were adjusted by DWR to reflect "normal" conditions of farmed acres and crop distribution that would have occurred in 1995 had weather patterns and water supply been "normal."

SEPARATING EVAPORATION
AND TRANSPIRATION

The terms evaporation, transpiration and evapotranspiration historic-ally have been used in the context of agricultural water use as follows:

Evaporation (E) is the conversion of liquid water to vapor. It generally refers to water evaporated from soil surfaces, flowing water in fields (furrows and sprinkler droplets) and water intercepted on plant leaves.

Transpiration (T) refers to water that passes through the plant and into the atmosphere as vapor. In addition to the climatic conditions that a plant is exposed to (solar radiation and atmospheric conditions), transpiration is affected by evaporation on or near the plant.

Evapotranspiration (ET) is the combination of evaporation and transpiration. The combined ET process is controlled or influenced by soil, crop, irrigation, and atmospheric factors. Evaporation from surrounding areas reduces transpiration, while the absence of evaporation from soil or wet plant surfaces increases transpiration (Burt et al.). However, little research has been completed that quantifies this relationship.

Since E and T are difficult to measure individually, the combined ET generally is used to calculate crop water use. This is not to imply that separating these factors could not provide insight into additional water conservation benefits. The CALFED Program acknowledges the potential for some conservation savings from reducing evaporation, especially evaporation from the soil surface.

For this document, however, CALFED did not attempt to separate these two factors because of limited availability of relational data. The Water Use Efficiency Program does include an action targeted at this information void in an effort to better understand the relationship between E and T so that more accurate conservation estimates can be made. In the interim, the data available to CALFED to estimate conservation potential are believed to still adequately estimate realistic conservation potential.

Actual 1995 conditions of applied water were lower because of wet hydrologic conditions that increased effective rainfall, thus decreasing applied water use. It is important to note that using normalized data instead of actual historical data for 1995 reduced the potential for over- or under-representing average applied water volumes and thus over- or under-representing conservation potential.

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For example, the actual acreage in 1995 may be greater than in other years because of ample water supplies. Using actual data that represent a higher than average use of water would result in over-estimating the average conservation potential.

The 1995 normalized data were used for estimating conservation potential because:

- Data were adjusted for changes in cropping and water management practices that have occurred since the 1987-92 drought and since implementation of portions of the CVPIA (as compared to normalized 1990 data used by CALFED for previous estimates).

- Represent the best information about conditions that provide a useful basis for estimating current conservation potential versus an uncertain projection of future conditions.

- DWR generates agricultural water use data for many small subareas throughout the state based on a multitude of data inputs, including land use and crop water needs. Each subarea is compiled into Planning Subareas (PSAs), which are a subset of the larger hydrologic regions often referred to during water use discussions (such as the Sacramento River and South Coast Regions.) As discussed in Section 3, the CALFED regions used to present information in this document are different from DWR's hydrologic regions, comprised by varying combinations of DWR's PSAs.

To estimate conservation potential for each CALFED region, three PSA data points were obtained from DWR:

- 1995 normalized agricultural applied water (AW)
- 1995 normalized agricultural depletions (DEP)
- 1995 normalized agricultural evapotranspiration of applied water (ETAW)

Table 4-1 summarizes the PSA data obtained from DWR (data have been aggregated for the CALFED regions described in Section 3).

Table 4-1. 1995 Normalized Agricultural
Water Use Data Received from DWR (TAF)

REGION[1]	APPLIED WATER[2]	DEPLETION[2]	CROP ETAW[2]
Sacramento River	6,278	4,321	4,096
Delta	1,116	780	758
Westside San Joaquin River	1,361	1,041	973
Eastside San Joaquin River	4,043	2,885	2,781
Tulare Lake	9,209	7,496	6,894
San Francisco Bay	97	86	74
Central Coast	48	39	38
South Coast	755	665	542
Colorado River	2,812	2,742	2,177
Total	25,719	20,055	18,333

[1] Refer to Chapter 3 for information regarding the PSAs that comprise each CALFED region.
[2] Data have been aggregated for the CALFED regions.

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4.7.2   ASSUMPTIONS USED TO INTERPRET AND ANALYZE DATA

The assumptions used to interpret and analyze the data are the second most important aspect of a technical analysis, only slightly less important than the input data. It is crucial for the reader to fully understand what assumptions were made to estimate conservation potential. This focuses the reader's attention on the assumptions and their impact on the results, not only on the results.

Estimating conservation potential for California's irrigated agriculture is difficult because of its complexity and variable conditions. The methodology used here was made as simple as possible, while still providing useful results, by using only the three input parameters shown in Table 4-1 and a handful of assumptions.

Assumptions are discussed below in more detail for each of the following:

a. Calculating "existing loss" and "irrecoverable loss" from input data, including:
    a. Defining losses and subtracting input data.

Once these values are determined, it is necessary to perform the next step:

b. Segregating losses into "conservable" and "nonconservable," including determining the amount of water:

    a. Necessary for leaching and
    b. Lost to channel evaporation and consumption by riparian and bank vegetation.

Finally:

(3) The conservable water is split into categories of the:

    a. No Action Alternative increment,
    b. CALFED increment, and
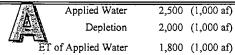   c. Remaining increment.

The following example table, similar to the specific regional tables provided in Attachment A, was included to illustrate how each assumption and sub-assumption is applied and how calculations were made. Letters (A, B, and C) were used to point the reader to the appropriate location on the example table as each assumption and calculation is discussed. The input data are shown in the example table at area "A."

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Figure 4-9 Determination of Potential Agricultural Conservation Savings

Example Region

Input Data from DWR

Applied Water	2,500	(1,000 af)
Depletion	2,000	(1,000 af)
ET of Applied Water	1,800	(1,000 af)

Assumptions for Calculations

1. Ave. Leaching Fraction = 5%

2. % lost to Channel Evap/ET [3] = 2%

3. Assumed allocation of conservation betw District and On-farm
   district portion = 1/3 of savings * "adjustment factor"

canal lining:	1	
tailwater:	1	(adjustment factor
flexibility:	1	based on region variation
meas/price:	1	in water districts)

4 (points for this region's districts
of 4 points for average)

1 = adjustment factor

33% = district portion
67% = on-farm portion

Calculations from Input Data

(1,000 af)

Total Existing Losses	700	(Diff betw. Applied Water and ETAW)
Total Irrecoverable losses	200	(Diff betw. Depletion and ETAW)
Total Recoverable losses	500	(Diff betw. Applied Water and Depletion)
Ratio of Irrecoverable Loss	29%	(Irrecov divided by total existing losses)
Portion lost to leaching	26	(Leach Fraction * ETAW * Irrec. Loss Ratio * Adj. Factor)
Portion lost to Channel Evap/ET	50	(Applied Water * % lost to Channel Evap/ET)
Total Loss Conservation Potential	624	(Total Existing loss - portion to leaching - portion to channel evap/ET)
Irrecoverable Portion	124	(Irrec loss - portion to leaching - portion lost to channel evap/ET)
Recoverable Portion	500	(Total Existing loss - Irrecoverable Loss Portion)

Incremental Distribution of Conservable Portion of Losses

		Distrib. Factor	Applied Water Reduction [1] (1,000 ac-ft)	Irrec. Loss Reduction [2] (1,000 ac-ft)	Rec. Loss Reduction (1,000 ac-ft)
No Action Increment =	1st 40%	0.40	250	50	200
CALFED Increment =	next 30%	0.30	187	37	150
Remaining =	final 30%	0.30	187	37	150
			624	124	500

Summary of Savings:

Existing Applied Water Use = 2,500

Total Potential Reduction of Application

(1,000af)	Existing	No Action	CALFED	Total
On-Farm	--	167	125	292
District	--	83	62	145
Total	700	250	187	437

Recovered Losses with Potential for Rerouting Flows

(1,000af)	Existing	No Action	CALFED	Total
On-Farm	--	133	100	233
District	--	67	50	117
Total	500	200	150	350

Potential for Recovering Currently Irrecoverable Losses

(1,000af)	Existing	No Action	CALFED	Total
On-Farm	--	33	25	58
District	--	17	12	29
Total	200	50	37	87

Notes:
1. Calculated as the distribution factor times the "conservable portion" of the total existing loss. The first 40% of savings potential occurs under *No Action*. The next 30% of saving potential is the CALFED increment. The final 30% is considered "non-conservable".
2. Calculated as the distribution factor times the "conservable portion" of irrecoverable loss. The first 40% of savings potential occurs under No Action. The next 30% of saving potential is the CALFED increment. The final 30% is considered "non-conservable".
3. Derived from comparing consumptive conveyance loss values from USBR *Least-Cost CVP Yield Increase Plan*, T.A #3 (Sept. 1995) to applied water values for the region. A range of 2 to 4% was used to account for uncertainty. This value accounts for consumption by bank and riparian vegetation and channel evaporation.

Calculating Existing Loss and Irrecoverable Loss from Input Data

Three kinds of losses need to be calculated from the input data to estimate conservation potential. These include:

- "Existing loss," which is determined by taking the difference between the AW and the ETAW. (This is equivalent to the total applied water reduction feasible if CALFED assumed 100% irrigation efficiency and no irrecoverable losses during delivery of the water to the plant—and that every drop of applied water is consumed by the plant with no water necessary for leaching or cultural practices.)

- "Irrecoverable loss," a subset of "existing loss," which is determined by taking the difference between the DEP and ETAW. (This is equivalent to the fraction of the total applied water reduction that could be made available to other beneficial uses—again assuming 100% irrigation efficiency.)

- "Recoverable loss," also a subset of "existing loss," is the difference between "irrecoverable loss" and "existing loss."

Calculating existing loss and irrecoverable loss is the basis of the agricultural water conservation estimate because these values are the only water available for conservation. For example, looking at area "B" on the example table, the loss values are determined as follows:

From the input data (area "A"):	AW	=	2,500
	DEP	=	2,000
	ETAW	=	1,800
Then:	Existing loss	=	2,500 - 1,800, or 700
	Irrecoverable loss	=	2,000 - 1,800, or 200
	Recoverable loss	=	700 - 200, or 500

In this example, irrecoverable losses are 29% of the total existing loss. This ratio is an important indicator of the mix of irrecoverable and recoverable losses in a particular region. The ratio will vary with each region because of such factors as varied climate, soil type, geography, and location of each agricultural field. For this document, each region's ratio is considered to be equal across the entire region, except for the Tulare Lake Region (see Tulare Lake information under the regional discussions later in this chapter), which is adjusted to account for differences in water quality as a result of two different primary water supply sources (the Delta and the eastern Sierra Nevada).

The calculated existing loss is a result of on-farm irrigation and district delivery methods. Applying water for too many hours, applying water in a non-uniform pattern across a field, spilling water through the end of a delivery system, and many other activities all are examples of how existing losses are generated. However, some of the existing losses are a necessary or unavoidable part of the on-farm management or water delivery to a field. Necessary or unavoidable existing losses include leaching of salts from the soil profile, evaporation from conveyance channels, and consumption by bank vegetation along open delivery canals. These kinds of losses are described in more detail later.

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As should be expected, the accuracy of these calculations is only as good as the input data provided. If the ETAW value is off by 5%, then the calculated loss value may be mis-representative. CALFED did not extensively review the input data received from DWR. However, the methods used by DWR to generate these data have been refined over many years by competent engineers and technicians. For this analysis, CALFED assumed that these data are as accurate as any available and well suited for portraying estimated conservation potential at a programmatic level.

The existing loss and irrecoverable loss values calculated from the input data are presented in Table 4-2. The regional discussion later in this section repeats this information. Again, Attachment A provides the detailed assumptions for each region.

Table 4-2. Losses Calculated from Input Data Received from DWR (TAF)

REGION[1]	EXISTING LOSS	IRRECOVERABLE LOSS[2]	LOSS RATIO (IRRECOVERABLE/ EXISTING)	RECOVERABLE LOSS[3]
Sacramento River	2,182	225	10%	1,957
Delta	358	22	6%	336
Westside San Joaquin River	388	68	18%	270
Eastside San Joaquin River	1,262	104	8%	1,158
Tulare Lake	2,315	602	26%	1,713
San Francisco Bay	23	12	52%	11
Central Coast	10	1	10%	9
South Coast	213	123	58%	90
Colorado River	635	565	89%	70
Total	7,386	1,722		5,664

[1] Refer to Chapter 3 for information regarding the PSAs that comprise each CALFED region.

[2] This is a subset of existing loss and represents the total potential if 100% of the applied water was used by the crop. However, since leaching of salts from the soil is necessary, other losses occur that are mostly uncontrollable (canal evaporation and ET of riparian and bank vegetation), and 100% efficiency is nearly impossible to obtain, the total calculated does not equal the total conservable.

[3] This is defined as the difference between existing loss and irrecoverable loss.

Segregating Losses into Conservable and Nonconservable

Conserving water is defined for this section as reducing the amount of water necessary for the continued beneficial uses of agriculture at existing levels. Therefore, conservation does not mean a reduction in the consumptive use by crops (land fallowing, crop shifting, and deficit irrigation are not considered "water conservation" measures). Also, conserving water is independent of whether the water conserved is available for reallocation to other beneficial uses (see previous discussion in Section 4.4, "Irrecoverable vs. Recoverable Losses").

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As previously stated, the losses calculated from the input data represent the total of a region's existing loss. However, all of this loss cannot be considered "conservable" because of the following factors:

- The technical limit of reaching very high average on-farm efficiency (see the previous discussion regarding on-farm irrigation efficiency improvements in Section 4.4).

- The need to leach salts from the soil profile to maintain a crop root zone capable of sustained productivity (referred to as the leaching requirement or leaching fraction).

- Evaporative and consumptive losses from district and field-level delivery ditches that are generally open and support riparian and bank vegetation (including trees, shrubs, and grasses). Delivering water in pipes to avoid evaporative losses is often not feasible because of the capital cost to build a high-capacity distribution system and the energy costs to operate it, if it is pressurized.

Although each of these factors contributes to the existing loss, they dictate what portion of the loss should be considered unavailable to conservation efforts. Thus, when these contributors are subtracted from the existing loss value, a more realistic estimate can be made of the conservation potential.

Of these contributors to existing loss, the water evaporated or consumed by riparian or bank vegetation is considered to be an entirely irrecoverable loss since its "use" removes water from the local hydrologic system (see previous discussion in Section 4.4, "Irrecoverable vs. Recoverable Losses"). Also, depending on the characteristics of each region, some or all of the water used for leaching is unavailable to the local water supply. For instance, water used to leach salts from some lands on the west side of the San Joaquin Valley is intercepted by subsurface drains and routed to evaporation ponds. Every acre-foot of this water is lost. On the other hand, some areas of the Sacramento Valley that need to leach salts find that their "leach" water simply flows to groundwater or back into surface water sources, available to others but slightly degraded in quality.

The losses just described are defined as irrecoverable but are not conservable since they are necessary parts of the water management dynamic. These losses are distinguished from losses resulting from poor irrigation methods or spills from district delivery systems that flow to a salt sink. The latter losses also are defined as irrecoverable but are conservable.

As a starting point for determining what water could be conserved, these irrecoverable, non-conservable contributors need to be subtracted from the total existing loss and, since they are defined as irrecoverable losses, they must also be subtracted from the irrecoverable losses shown in Table 4-2.

Since empirical information primarily exists for estimating leaching requirements and channel evaporation and bank consumption, two of the three factors associated with nonconservable losses, only these factors initially can be subtracted from the existing loss values. Estimating water unavailable to conservation as a result of technical limitations is more difficult to calculate and is therefore handled in a different manner (see later discussion regarding "Distributing Conservable Water Across a Range of Efficiency Improvements"). A more complete discussion of how these values are derived follows.

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Calculating Nonconservable Water

Water deemed "nonconservable" is water that is necessary for sustainable agricultural productivity but contributes to the total existing loss. This amount includes water used to leach salts, as well as water evaporating from delivery canals, or being consumed by riparian or bank vegetation growing along the delivery system channels and drains throughout the state.

The nonconservable portion must first be subtracted from the calculated losses to estimate conservable water. To do this, CALFED made assumptions to estimate leaching requirements and evaporation and consumption along delivery canals.

Leaching Requirement. The leaching requirement is defined as "the fraction of infiltrated irrigation water that percolates below the root zone necessary to keep soil salinity, chloride, or sodium (the choice being that which is most demanding) from exceeding a tolerance level of the crop in question. It applies to steady-state or long-term average conditions" (Soil Science Society of America web page July 1998).

To estimate the leaching requirement for most fields, an empirical relationship between irrigation water salinity (if this is the parameter of concern) and the desired salinity level in the root zone (based on a crop's threshold) is used. It is calculated using the formula developed by the USDA-Salinity Laboratory and taking the idealized root zone salt accumulation pattern for surface irrigated soil:

$$YR = ECUS/(5ECe-ECUS)$$

where ECUS is the salinity of irrigation water and ECe is the soil salinity of soil saturation extract. The threshold salinity level is the maximum soil salinity that does not significantly reduce yield below that obtained under nonsaline conditions. (Maas and Hoffman 1977.) For cotton and tomato, which have a very high tolerance to salinity, the threshold salinity levels are about 7.7 dS/m and 2.5 dS/m, respectively. For a similar soil profile—based solely on the aspect of salinity, assuming no changes in soil salinity throughout an irrigation season and no groundwater contribution to the plant water requirement—the YR ratio is constant within a fixed geographic location. However, the net depth of applied irrigation water for the same crop and similar soil, irrigation quality, and irrigation method might not be the same due to differences in climatic conditions in different parts of the state. This is because irrigation leaching depth is:

[(ETAW - effective precipitation + other cultural practices) * leaching requirement percentage]

Since ETAW for the same crop, precipitation, and cultural practices may vary from one geographic location to another and from one field to another, net irrigation leaching depth also varies accordingly. Another factor affecting the depth of irrigation leaching requirement is irrigation DU (the evenness of irrigation water application over a field, as discussed previously), which may contribute to leaching salt from the root zone. Therefore, excess irrigation water due to non-uniformity may help leach irrigation salt buildup in some parts of a field and, in return, reduce the irrigation leaching requirement depth for portions of a field.

However, all of this information is specific to individual fields, and the formulas are difficult to use for determining average leaching requirements across an entire region. Therefore, to estimate the amount of existing loss generated from leaching for each region, CALFED made assumptions, based on professional judgement, about the average leaching requirement in each region. Spot checking these assumptions with the formula supported this approach.

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To account for variation in leaching requirements and the uncertainty of knowing the exact requirement when considering DU and other variables, a range of values was used for each region (see Table 4-3). To calculate the volume of total loss contributed by leaching, the leaching requirement was multiplied by the ETAW and the loss ratio values shown previously in Table 4-2. The resulting values were subtracted from the existing loss and the irrecoverable loss, respectively, to help estimate conservation potential. As illustrated on the example table, the leaching requirement ("C") was multiplied by the ETAW ("A") and the Ratio of Irrecoverable Losses ("B"). This results in an assumed loss derived from the water necessary for leaching ("E"). For each of the CALFED regions, the leaching requirements shown in Table 4-3 were assumed, resulting in the "loss from leaching."

Table 4-3. Range of Leaching Requirement Volumes

REGION	ASSUMED LEACHING REQUIREMENT[1]	RANGE OF POSSIBLE LOSS FROM LEACHING REQUIREMENT[2] (TAF)
Sacramento River	2-4%	8-17
Delta	4-6%	1-2
Westside San Joaquin River	10-14%	17-24
Eastside San Joaquin River	2-4%	5-9
Tulare Lake	8-12%	179-269
San Francisco Bay	4-6%	1-2
Central Coast	4-6%	0-1
South Coast	10-14%	41-57
Colorado River	10-14%	194-271
Total		**446-652**

[1] These percentages represent average leaching requirements for each region. Source water quality dictates higher leaching requirements. For example, water salinity levels in the Sacramento Valley are low but levels in water exported from the Delta to the west side of the San Joaquin Valley and parts of the Tulare Basin are 10 times higher. The Tulare Lake Region has salinity levels that range from high for areas receiving Delta water to low for areas receiving water from the Sierra Nevada. These values are based on professional judgment, following discussion with several irrigation experts.

[2] These values were calculated by multiplying the leaching requirement percentage by the evapotranspiration of applied water and the loss ratio presented in Table 4-2. They are defined as irrecoverable losses but are not conservable. Subtracting them from the total existing loss helps estimate remaining conservation potential. Subtracting them from the total irrecoverable loss helps estimate the conservation potential that is available for reallocation to other purposes.

Channel Evaporation and Consumption by Riparian and Bank Vegetation. Channel evaporation and conveyance consumption also are defined as irrecoverable losses and are considered nonconservable. Therefore, these amounts need to be subtracted from the total existing loss for a more accurate estimate of conservation potential.

Hundreds of miles of irrigation delivery canals, channels, and drainage systems move water from surface and subsurface sources to or away from farm fields throughout the state. Most of these systems are open channels with vegetation on both sides. Enclosing these channels and canals or removing all of the natural vegetation is not practical for most water suppliers, although it may be ideal from a water management standpoint. In many instances, the vegetation systems that have developed along some of these channels provide important riparian habitat in areas where the rest of the land is dedicated to production agriculture. Furthermore, the cost to convert delivery and drainage channels to pipelines in order to reduce evaporation is not cost effective for most water suppliers.

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